THE TELIDON ROAD/WEATHER INFORMATION SYSTEM (RWIS): USER EVALUATION DURING 1985–86 WINTER TRIAL

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THE TELIDON ROAD/WEATHER INFORMATION SYSTEM (RWIS): USER EVALUATION DURING 1985/86 WINTER TRIAL

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The Operations and Technology Office, Communications Division, is developing and field testing the Telidon Road/Weather Information System (RWIS) at the request of the Maintenance Operations Office, Maintenance Branch. The Human & Social Factors Office has been requested to conduct a user oriented evaluation of RWIS by Operations and Technology, with the agreement of Maintenance Operations. The involvement and advice of these two offices and the cooperation of management and staff responsible for maintenance in District 6 are gratefully acknowledged.

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1.0 EXECUTIVE SUMMARY

This report describes results that have been accumulated during a preliminary evaluation of the Telidon Road/Weather Information System (RWIS). The RWIS system is a computer based service that distributes information about road and weather conditions to Ministry of Transportation and Communications' (MTC) personnel in public information and maintenance operations services. The purpose of the evaluation was to evaluate RWIS from the user's perspective, and to make recommendations about future development, implementation, and training.

From the results of a limited trial, we have provisionally concluded that RWIS is a potentially useful decision support system for managing winter operations, provided that personnel at the Maintenance Operations patrol level could have direct access to RWIS terminals. We have also concluded that patrols would only have to achieve modest operating savings relative to their total winter maintenance costs to justify the investment of installing RWIS terminals at the patrol level. To substantiate our provisional conclusions, we recommended that the RWIS trial be extended into the 1986-87 winter season to assess whether or not giving patrol personnel RWIS terminals would yield the required benefits. In the following summary, we will briefly review the progress of the evaluation, and the reasons for our recommendations.

1.1 Description of RWIS

RWIS is a videotex information system. It is maintained on a central computer, and users gain access to the system from remote terminals that are connected to the computer through conventional telephone lines. A terminal gives the user access to 15 information functions. Six functions contain information about current weather conditions; five functions contain weather forecast information; and four functions contain information about road conditions.

The RWIS terminal video display unit presents information by means of coloured text and graphics displays. RWIS displays are designed to be self-explanatory. Weather information includes weather maps, weather radar displays, and ordinary text displays. The road information includes maps of District highways, colour coded to represent road conditions, operations in progress, and driving conditions. Most RWIS commands can be performed by making menu selections or by typing keyword commands on a keyboard.

RWIS information comes from two main sources. The Atmospheric Environment Service supplies weather information; and MTC District Maintenance patrols supply road information. One of the RWIS functions is an input function that can be used by MTC personnel to enter road and weather information into the RWIS computer. The RWIS data base is available 24 hours a day, and is amended at intervals varying from every 10 minutes to every 24 hours depending on the type of information being amended.

1.2 Design of the Evaluation

RWIS was installed for testing in Districts 6 (Toronto), 8 (Kingston), 9 (Ottawa), and 10 (Bancroft) beginning in February, 1986. Terminals were also installed in the Road Information Office (RIO), and in York Region. However, the evaluation being reported here was conducted only in District 6, and in the RIO. In District 6, terminals were installed in the District Office, and the Radio Room.

For the purposes of the evaluation, RWIS users included District 6 maintenance operations personnel, Radio Room personnel, and RIO personnel. Two categories of users were defined; direct users, and indirect users. Direct users were persons who had direct access to the terminals. Indirect users were persons who did not have access to terminals, but who could be expected to exploit RWIS services through the direct users.

The evaluation design had two general aims. One was to find out how users could apply RWIS services in their jobs. The other was to assess the ease of use of RWIS. The evaluation method contained five components designed to achieve these aims. The components were:

1) a task analyses of the users jobs to determine what job tasks would be affected by the use of RWIS;

2) a human factors assessment of the RWIS user interfaces;

3) a critical incident analysis, which amounted to doing an analysis of the potential for using RWIS in managing operations in response to winter storms;

4) monitoring of the operations management and control systems that were expected to be affected by RWIS; and

5) a user opinion survey to be conducted at the end of the trial.

This report covers results mainly from the first three components of the evaluation method. There were only limited amounts of data available for monitoring operations; and the short duration of the trial made the final user survey unnecessary.

1.3 Results

Both the user task analysis and the critical incident analysis showed that the primary application of RWIS services was in the management of winter maintenance operations at the level of individual patrols. Almost all of the outcomes of a patrol supervisor's decision making are affected by how accurately the supervisor anticipates weather conditions. The impact of weather is, of course, greatest when the supervisor is managing operations in preparation for, and during a winter storm. Because day-to-day maintenance

operations are controlled at the patrol level, personnel above the level of the patrol are not so concerned by day-to-day weather conditions.

The RIO's major function is to distribute information to mass media. Although RWIS provides a convenient way for an individual to get information about road conditions, it is not particularly suited to be a primary information source for the mass distribution services as currently provided by the public information personnel. In addition, RWIS does not provide much road information that is not already available in existing reporting systems. Although RIO personnel appreciated the convenience of RWIS, in the short time that RWIS was available to RIO personnel, no major applications of RWIS were found that would affect RIO current operations.

The review of the RWIS user interface found that the system was generally well designed, and easy to use. However, a substantial number of specific design improvements were identified. For the most part, the improvements concerned design inconsistencies, and system characteristics that interfered with the user's ability to absorb information from the displays.

Although the RWIS is easy to use, much of the information is meteorological data that normally only people who have some training in meteorology can interpret and use. Generally, the users did not have such training. For RWIS to be used effectively, the users need to be given some, but not extensive training in meteorology.

The review of the interface between direct users and indirect users showed that there were no procedures in place to permit indirect users to have meaningful access to the system. Nor did it appear to be practical to attempt to pass RWIS information to indirect users, such as patrol personnel, by having terminal operators access and interpret RWIS information for indirect users. RWIS information is not the type of information that a terminal operator can pass on to another person the way an airline clerk can inform a caller about the status of a plane reservation. To interpret and apply the information from RWIS, the user has to have direct access to the RWIS terminal.

The interface review showed that RWIS weather information corresponds well with the types of weather information that maintenance patrol personnel could use in managing patrol operations. But because the patrol personnel did not have access to RWIS terminals during this evaluation, there was no way of assessing how useful RWIS information would be in practice. For this reason, we explored whether or not it would be worth modifying the trial to test the effects of having RWIS terminals installed at a sample of patrols.

To assess the value of modifying the trial to include patrol level RWIS installations, we performed a cost-benefit analysis to see if the cost of RWIS operation could potentially justify patrol level installations. The analysis showed that RWIS would be a good investment if an average patrol could save about 1000 dollars a month during its winter operations due to having access to RWIS. Compared with patrols' winter operations budgets, and

in view of the impacts of weather information on patrol efficiency, a savings of 1000 dollars per month would not be an inordinate amount.

We recommend conducting a test with patrol RWIS installations, provided that Maintenance Branch management judges the required savings target to be realistic enough to make it worth testing the effects of installing RWIS at patrols. We also recommend that training patrol personnel in how to use weather information be a condition of testing patrol RWIS installations.

The Telidon Road/Weather Information System (RWIS) User Evaluation During 1985-1986 Winter Trial

2.0 INTRODUCTION

This report describes the results that have been accumulated in an evaluation conducted during the first winter trial of the Telidon Road/Weather Information System (RWIS). The system consists of a Telidon service that distributes information about road and weather conditions to personnel in road maintenance and public information services. The RWIS system was accepted for testing and evaluation by the Ministry of Transportation and Communications (MTC) in the late part of the 1985-1986 winter season. The purpose of the evaluation was to assess the usefulness of RWIS from the user's perspective, and to make recommendations about future development, implementation, and training support.

This report will be set out in four sections. In the first section we will briefly describe RWIS' functions, and the structure of the evaluation trial. Then we will describe the evaluation method. Next we will describe evaluation results. Finally we will present conclusions and recommendations based on these findings.

3.0 DESCRIPTION OF RWIS AND THE STRUCTURE OF THE RWIS TRIAL

In the first part of this section, we will briefly describe how RWIS works. Then we will give an overview of the structure of the trial.

3.1 RWIS System Description

RWIS is a videotex information system that distributes road and weather information. The system is designed primarily for use in two MTC functions; road maintenance operations and public information services. In road maintenance operations, RWIS provides weather information that maintenance personnel can use for deciding on deploying equipment, materials, and personnel for maintenance operations. In public information services, RWIS provides information about road and weather conditions that public information personnel can pass on to members of the public, either directly, or through distribution to local media.

RWIS is maintained on a central computer. Users gain access to the system from remote terminals through conventional telephone connections. The RWIS terminal consists of six components:

1) a high resolution colour television monitor;

2) a modem for communications with the central computer;

3) a conventional computer keyboard for issuing RWIS system commands;

4) a thermal printer that produces a 11.6 cm. by 8.7 cm. black and white copy of the monitor display;

5) a remote hand-held commander that can be used to issue commands instead of using the computer keyboard; and

6) a device videotex decoder that decodes the videotex signal for display on the television monitor; and links together the monitor, modem, keyboard, printer, and remote commander.

When the RWIS terminal is turned on and connected to the central computer, the system displays a menu of 15 information functions. Six of the functions provide information about current weather conditions. Five of the functions provide weather forecast information. Four more functions provide information about road conditions. In addition to the information functions, there is a function that can be used by authorized personnel for entering information into the RWIS data base. There is also a 'Help' function, and a function used for exiting from the system.

The user can make a menu selection by typing the number of the selection on the computer keyboard, or by punching a selection number on the remote commander. When a selection is made, the system produces either a graphic or a text display that contains the information described in the menu label.

We will give details of the contents of each of the system pages (displays) later on as part of the user interface review. For the time being, we will give a brief overview of the types of displays that are available on the system. Three types of display are used for conveying weather information; weather maps, weather radar displays, and text displays containing weather data. The geographic scope of the weather information pages varies from coverage of almost all of North America for some types of weather map information, down to coverage of individual MTC Districts for temperature and precipitation data.

The road information pages show maps of the highways in each District. Depending on the display, the roads are colour coded to indicate either the current driving conditions, or what maintenance operations are currently under way. One of the road information functions also contains longitudinal cross-sections of major roads showing road and weather conditions on heavily travelled routes such as the highway between Toronto and Montreal.

In addition to being able to view individual system pages, the user can obtain a dual display showing two system pages side by side; for example, a display showing the Exeter weather radar display on the left, and the King City weather radar display on the right. To produce the dual displays, the system has to fore-shorten the horizontal axis of each page so that both will fit on the screen side by side.

The information displayed by RWIS comes from two sources. The weather information is supplied to the central computer from the Atmospheric Environment Service (AES) of Environment Canada. The road information comes from District road maintenance personnel. One of the RWIS main menu functions can be used by authorized District personnel to enter road reports directly into the system. If RWIS were fully implemented, a user could obtain weather and road information for any MTC District in the province. For the evaluation trial, District level information was available only for Districts 6 and 9.

3.2 Structure of the Evaluation Trial

RWIS was installed for testing in four MTC Districts; District 6 (Toronto), District 8 (Kingston), District 9 (Ottawa), and District 10 (Bancroft). Our evaluation activities were conducted only in District 6. For the trial in District 6, two RWIS terminals were installed; one in the District Radio Room, and one in the District 6 Headquarters. In addition, a terminal was installed in the MTC Road Information Office (RIO). The RIO is an MTC Headquarters unit providing public information for the province as a whole. It is also a hub for the general collection and distribution road and weather information. However, since it is physically located in District 6, it also provides the local District information function. Therefore, we included the RIO in the evaluation.

For the purposes of the trial, we defined two types of users; direct users and indirect users. Personnel in the District Radio Room and in the RIO were defined as direct users. These personnel had direct access to RWIS terminals. Passing information obtained from the terminals to other users was an implicit part of the functions of the Radio Room and the RIO. Indirect users were defined as District 6 management and supervisory personnel in road maintenance operations. These included the personnel who make the day-to-day operating decisions at each of the District patrols. We characterized the procedures for passing information from the direct users to the indirect users as implicit job functions because there were no formal procedures developed either for requesting RWIS information, or for distributing it.

The RWIS system became operational in February, 1986. However, the individual terminals were not installed all at once. The District 6 Radio Room received one of the first terminals. The RIO did not receive a terminal until late March. Because of the timing of the implementation, RWIS did not

get much use in its intended role of supplying information support for managing winter operations. Consequently, the evaluation activities were restricted largely to gathering information about the operations that RWIS was intended to support, and about the potential applications of RWIS in these operations. The next section describes the details of the evaluation method.

4.0 EVALUATION METHOD

The original evaluation design contained five components. But because the RWIS trial started later in the winter season than originally anticipated, only the first three components, and part of the fourth component, were conducted. The five components of the original design were:

1) task analyses of the user's jobs to determine what job tasks would be affected by the use of RWIS;

2) a human factors assessment of RWIS;

3) critical incident analyses of the use of RWIS;

4) monitoring of the operations management and control systems that were expected to be affected by RWIS; and

5) a user opinion survey.

We will describe each evaluation component in turn.

4.1 User Task Analysis

The purpose of the task analysis was to obtain descriptions of the job functions of the RWIS users, and in particular, descriptions of job tasks that would be affected by the use of RWIS. The task descriptions were to be used to derive descriptions of the impacts of RWIS.

Users were defined as personnel whose operational responsibilities would be significantly affected by the use of RWIS. These included personnel who had direct access to RWIS terminals, operating personnel whose day-to-day tasks could be affected by information acquired from RWIS, and management or supervisory personnel whose operations could be affected by how subordinates used RWIS.

The task analysis information was collected in personal interviews. An interview sample was developed from MTC organization and job description

documentation, and from discussions with MTC management and staff. The interview program began with interviews of senior management users, and progressed to interviews of more junior personnel. Most of the interview contacts were made through users' immediate superiors. The management personnel helped to identify specific users to include in the interview sample to make the sample representative of different types of users. Since we were dealing with a relatively small organization, we did not attempt to impose any rigorous random sampling for identifying people to be interviewed.

The task analysis interview was generally conducted as an open-ended job analysis interview. In the first part of the interview, the user was asked to describe his or her major job tasks. For each task, the user was asked to describe how the task was performed, why it was performed, and when or how often the task was performed. As the interview progressed, tasks that could be affected by RWIS were identified. For each such task, the interviewer attempted to explore exactly what impacts RWIS would be likely to have on the performance of the task. The structure of the interview was varied depending on the seniority of the person being interviewed. For more senior managers, the focus of the interview was on general functions that might be affected by RWIS. For operating personnel, the focus was on specific tasks that might be affected by RWIS.

4.2 Human Factors Assessment of RWIS

The purpose of the human factors assessment was to evaluate the degree to which the design of RWIS permitted users to make effective use of the system. In a conventional human factors assessment, this assessment would be concentrated on the design of the interface between the operator and the system terminal. However, the RWIS user group consisted of two types of users: a relatively small number of direct users who operated the RWIS terminals, and a larger number of indirect users who received RWIS information at second hand from the direct users. Thus there were essentially two user interfaces; one between the RWIS terminal and the direct user, and one between the direct user and the indirect user. To make the human factors assessment comprehensive, we reviewed both interface components.

For reviewing the direct user interface we planned to review the system operating and training documentation, and then use this documentation to conduct a systematic review of each of the system functions. There was in fact little documentation available. For the systematic interface review, we did a hands-on review of all of the system functions, and for each function, compared the characteristics of the function with published design guidelines. The primary guideline sources were from Smith and Aucella, 1983; Engel and Granda, 1975; Ramsey, Atwood, and Kirshbaum, 1978; Badre and Shneiderman, 1982; and Kantowitz and Buck, 1983.

We had also planned to identify a sample of system operating procedures that could be used as exercises for observing how well direct users could

cope with operating the terminal. As it turned out, the operating procedures were quite simple, so it was not worth structuring formal operator test sessions. Instead, we observed users informally during interviews, and noted any problems mentioned by any of the users.

For the direct user - indirect user interface, we developed flowcharts of the routings of RWIS information going from the direct users to the indirect users. The charts were used to assess the timing and completeness of the information flows, and in combination with data from the task analyses, to identify ways in which indirect users could make use of RWIS information. We particularly sought evidence about whether or not RWIS information could be used effectively in operations decision making.

4.3 Critical Incident Analysis

Critical incident analysis is a commonly used technique for analyzing job activities that are episodic in nature. For example, a bank teller's activities can be described as a set of critical incidents representing the different types of customer transactions handled by the teller.

In the case of RWIS, the operational responses to winter storms can be treated as critical incidents representing the application of RWIS capabilities. Indeed, a major purpose of RWIS was to improve the abilities of MTC's maintenance and information functions to respond to winter storms. Information from RWIS would keep the public informed up-to-the-minute about road conditions during periods when road conditions were likely to be changing; and RWIS information would better enable maintenance personnel to deploy the correct types and amounts of equipment during changing storm conditions.

The critical incident analysis was to be conducted by observing operations during a winter storm; and through debriefing sessions to be conducted after the storm. Because RWIS implementation occurred late in the winter season, no major storms occurred during the period of evaluation activities. There was however, a minor storm while the task analysis interviews were being done; so this provided an opportunity to gather some critical incident information during the task analysis interviews. As it turned out, most of the operating personnel had a natural inclination to describe their job functions in terms of responses to storms.

By the end of the task analysis interviews, we had enough information to be able to reconstruct the operations activities in response to a storm. As a check on the accuracy of our analysis, we reviewed our analysis of events with a line maintenance supervisor. This review was conducted in front of an RWIS terminal so that we could explore how specific RWIS functions could be used in the operations decision making that went on during a storm.

4.4 Monitoring of Impacts

This evaluation component was to consist of collecting RWIS usage statistics, and any management information statistics that might be expected to show effects due to the use of RWIS. In addition, provision was made for keeping in touch with selected users who could keep us informed about any day-to-day events that might affect system usage or the evaluation findings.

We did not find any management information that would be of use to the evaluation during the period covered by this report. We did receive some RWIS usage statistics, but because they were incomplete and covered a period when users were largely exploring the system, we judged that it would not be proper to try to draw any conclusions from them. The contacts that we established with users were used mainly to check or clarify specific items of information that were collected during our other data gathering activities.

The information collected as part of this component of the evaluation method did not constitute substantive evaluation results, nor did they lead to any significant evaluation conclusions. Therefore, we will not report any results for this component.

4.5 User Opinion Survey

The User Opinion Survey was to be conducted at the end of the evaluation after the users had gained substantial experience with RWIS. The survey's purpose was to provide quantitative information about users' opinions on specific evaluation issues identified earlier in the evaluation. Because the system was implemented relatively late in the season, the users did not have time to develop substantial or consistent views on the various issues that were to be explored in the survey. Thus the survey was not conducted.

5.0 RESULTS

We will begin this section by describing the data sources that provided the results. Then we will describe the results of the user task analysis, the user interface assessment, and the critical incident analysis. At the end of the section, we will present some incidental findings that were acquired during the formal data gathering activities.

5.1 Evaluation Data Sources

The results were derived from three types of data; documentation, personal interviews, and direct observations made on RWIS terminals by the

evaluation team. Documentation consisted of RWIS system specifications, vendor literature describing the RWIS terminal components, organization charts, and job descriptions. During the trial, there was no RWIS user support documentation such as a user manual or training documentation.

The evaluation project manager, and the RWIS development project manager provided various types of background information as needed during the evaluation. In addition, a manager in Headquarters Maintenance Operations provided a general overview of the province's road maintenance functions.

The task analysis interview sample frame is shown in Table 1. The patrol level personnel represented five out of the 14 patrols in District 6. The patrol personnel also represented the three basic types of District 6 patrols; urban freeway patrols, rural patrols, and rural-freeway patrols. The task analysis sample was consistent with the evaluation plan except that only one instead of several Radio Room personnel were interviewed. The Radio Room operation was smaller than originally anticipated, so there was no need to conduct more than one interview.

Direct observations of the RWIS terminal were made during three sessions: one session was a familiarization session, the second was a detailed review of the system functions, and the third was a review conducted with a user. Additional incidental observations were made during interviews with users.

5.2 User Task Analysis Results

We will first describe the user organization. Then we will describe individual job tasks in terms of applications of RWIS. At the end of the section we will describe any general applications of RWIS that were mentioned by a majority of users independent of their job functions.

5.2.1 The User Organization

Figure 1 shows a schematic functional organization chart that describes the organizational relationships within the user group. The chart shows only those positions that could be affected to some degree by the use of RWIS. The box for each position contains a brief list of the responsibilities and tasks associated with the position. Where the box on the chart represents several actual positions, the actual number of positions is shown in the box.

As the descriptions of the functions shown in the chart imply, the patrols, the Radio Room, and the RIO are the functions that could be directly affected by the use of RWIS. The RIO received an RWIS terminal to use as an information source for informing the public about road and weather conditions. The Radio Room was responsible for entering information from the patrols into the RWIS data base. The Radio Room was also responsible for distributing RWIS information to the patrols.

Managers and supervisors in positions above the operating levels would be affected by RWIS only to the degree that use of RWIS affected the performance of their subordinate operating units. Although the District Maintenance Supervisors had an RWIS terminal, it is not clear that District Office personnel could use RWIS to support their own decision making. District Office decision making applies to longer term program decisions, while RWIS functions are designed to support day-to-day operational decision making. Thus, senior supervisory and management personnel are stakeholders rather than users in the application of RWIS.

5.2.2 RWIS Applications in the RIO

A major function of the RIO is to supply information about road conditions to outside individuals and agencies. Outside agencies include the media, municipalities, transportation authorities, and other ministries. Information is sent outside on wire services, by telephone, and in the form of press releases. The RIO receives its information about road and weather conditions in the form of written summaries from the Radio Room. These summaries are derived from reports sent by radio from each of the Districts. The RIO also distributes weather information from AES to the District radio rooms. In winter, the RIO operates 24 hours a day. In summer, the RIO operates on only a day shift.

The RIO had only a limited opportunity to try to use RWIS. Nevertheless, it did not appear that RWIS would necessarily produce substantial changes in the nature of the services provided by the RIO. The road and weather information that patrols supply for the RWIS data base is the same information that the RIO receives through the current reporting system. The RIO also receives AES weather reports, so the weather information contained in RWIS is not so much new information as it is more detailed information presented in a different medium.

If RWIS were installed in all of the Districts, it could substitute for the present road conditions reporting system. Being able to turn on the RWIS terminal would also mean more convenient access to road conditions information. If the road information were kept up-to-date, the RIO could be more confident that information supplied to the public was up-to-date.

One could imagine RWIS being useful to RIO staff who answered telephone enquiries from individual members of the public. If a caller wanted to know about conditions for a certain road, the RIO staff member could quickly get the information from RWIS and pass it on to the caller. At present, when members of the public call the RIO telephone number for road information, they get a pre-recorded message describing current road conditions. If a caller stays on the line after the end of the pre-recorded message, an RIO staff member will pick up the line and answer questions that were not answered in the pre-recorded message. In fact, however, few callers try to get beyond the pre-recorded message. In addition, the RIO is not staffed at

a level that would allow it to handle a high volume of individual calls; thus, it seems unlikely that there would be much demand for using RWIS in this way.

Because the RWIS terminal was installed in the RIO at the end of the season; in fact, only a few days before the RIO converted back to summer operations; there was little opportunity for the RIO to explore applications other than discovering that RWIS was convenient for reviewing or retrieving road and weather information. With greater opportunity to use RWIS, the RIO staff might have discovered other applications.

5.2.3 RWIS Applications in the District Radio Room

The District 6 Radio Room is the centre of a radio communications network consisting of 17 base stations, about 140 units in vehicles, and five repeater stations. As well as providing communications links among District 6 personnel, the Radio Room is a communications relay to and from outside agencies such as the police, emergency services, and transportation authorities.

The Radio Room handles two types of communications; episodic communications, and communications connected with regular reports. An example of episodic communications would be communications between the police and maintenance personnel in connection with an accident.

The communications connected with regular reports are all associated with reporting road and weather information. There are two main regular reports; one coming in from the patrols, and one that is sent out to the patrols. The outgoing report consists of an AES weather forecast relayed from the RIO to the patrols twice a day. The incoming reports consist of reports from the patrols on road and weather conditions. These reports are sent in five times a day; six times a day in the case of urban patrols. To get the road reports, the Radio Room polls each of the patrols at prearranged times. Each patrol reports its road conditions, its current maintenance operations, and a set of weather data that includes wind direction and speed, temperature, precipitation, and visibility. After it receives the reports from the patrols, the Radio Room prepares a summary report which is sent to the RIO. This summary report is also sent by teletype to other Districts, and to some outside agencies such as the Ontario Motor League.

With the installation of RWIS, the Radio Room has become responsible for entering data from the patrol reports into RWIS. This amounts to directly typing data from the patrol reports into the RWIS terminal. The data entry process does not require much interpretation of the information in the patrol reports, but the process is time consuming to the degree that it might be difficult for the Radio Room to keep RWIS up-to-date during busy periods without a shift in priorities.

The Radio Room is also the source that the patrols would use to get

information from RWIS. During the evaluation period, there was no formal procedure for doing this. The Radio Room did not relay information from RWIS to the patrols at regular times. Occasionally patrol personnel called in for RWIS information, particularly for the status of the radar display. In general, there was little use of RWIS for supplying information to the patrols.

5.2.4 RWIS Applications at the Patrols

The boxes at the bottom of the chart in Figure 1 represent, as well as specific job positions, the fourteen maintenance yards distributed throughout the District. These yards are the physical locations from which the patrols operate. There are three basic types of patrols; rural, urban, and combined rural/freeway. Rural patrols contain predominantly two-lane highways. The urban patrols operate on the freeways in or close to metropolitan Toronto. The rural/freeway patrols operate in areas that contain both two-lane highways and freeways.

In winter, the rural patrols operate with a staff complement of generally less than 10 MTC personnel in each patrol. The staff complements of urban and rural/freeway patrols are generally twice as large as those of the rural patrols. During winter, all of the patrols also control work crews and equipment supplied by contractors. On average, about half of a patrol's winter maintenance operations are performed by contractors. In summer, the patrols' MTC complements are reduced by about half; and there are no contractors except for specific maintenance projects.

The patrols would be affected by RWIS to the extent that they could use RWIS weather information to decide on deploying personnel, equipment, and materials for maintenance operations. In fact, a critical feature of the maintenance organization is the fact that the decision making about day-to-day operations is done at the patrol level. If there is a storm for example, it is patrol personnel who decide exactly how to respond. In contrast, supervisory and management personnel above the patrol level are concerned with the longer term performance of the patrols.

The daily operational decision making at the patrol level is controlled by a person in a function that is not explicitly shown on the organization chart. This is a function called patrolman. During the day, the patrolman is normally the patrol's supervisor or foreman. When the patrol's supervisor is off duty, a senior patrol staff member serves as patrolman. The patrolman's job is to patrol the roads covered by the patrol, and to call out the necessary resources when maintenance service is required.

The area covered by a patrol is small enough so that the patrolman can inspect all of the patrol's roads in a matter of hours. This also means that during winter maintenance operations the patrolman, or the patrol supervisor, can directly control operations by assigning individual crews to specific tasks. We will describe in more detail later the various conditions under

which the patrolman has to decide on calling out resources. For the time being, we will note that the patrolman is the person who has an obvious interest in knowing the weather conditions at any particular time.

As described earlier, no specific procedures were devised for regularly distributing RWIS information to patrol personnel. Thus the installation of RWIS has had little impact on patrols. Although almost all of the patrol supervisors have seen demonstrations of RWIS, none of the patrols have had direct access to an RWIS terminal. As described in connection with the Radio Room, and the RIO, the main connection that the patrols have had with RWIS has been to supply the reports that go into RWIS. In addition, patrols have occasionally received warnings about weather conditions, either from the Radio Room, or from supervisors who had access to an RWIS terminal in the District Office. Similarly, patrol personnel have occasionally called in to ask about weather conditions.

5.2.5 General RWIS Applications

Almost all users mentioned using RWIS records as evidence in lawsuits alleging negligence on the part of MTC in carrying out its road maintenance responsibilities. According to users, questions often arise in such suits about the state of road and weather conditions. Most users thought that RWIS records could be used to defend MTC against such allegations. We were unable to obtain any information to substantiate whether or not RWIS records would in fact serve this purpose. Nor were we able to obtain any information to substantiate whether or not the costs of this type of litigation represent a significant expense in comparison with general road maintenance costs.

5.2.6 Overall Impact of RWIS on User Tasks

From reviewing all of the organizational functions that are related to applications of RWIS, the main application of RWIS appears to be at the patrol level. The system provides easy access to road information, and to a great deal more weather information than was available to users before RWIS was installed. Although the users in this trial who had direct access to RWIS terminals said that they liked RWIS, they found it difficult to articulate ways in which they could substantially increase their effectiveness or productivity by virtue of having access to RWIS. In contrast, users at the maintenance operations level, who did not have RWIS terminals, were quite articulate about how having better weather information might enable them to improve their operations.

5.3 Human Factors Assessment

In this section we will first review the interface between the direct user and RWIS. Then we will review information flows between indirect users and RWIS.

5.3.1 RWIS Direct User Interface

As part of the review of the interface between the direct user and RWIS, we will give descriptions of the individual RWIS displays. For each display we will describe any problems that were observed in connection with the display, and suggest any improvements that might be made. Following the findings for individual displays, we will present any findings that apply to the system as a whole. The review findings are drawn from direct observations made according to the methods described earlier, and from comments made by users during interviews. At the end of the section we will give some brief comments on the user manual.

When the review was conducted, there was no user manual or other system documentation available to guide the review. A user manual was produced after the review was completed, and after the period during which RWIS was in operation. From reading the manual, we found that there were several system features that we did not observe or test because we did not find out about them until we saw them described in the manual. Since RWIS was no longer available, it was not possible to go back and observe the operations of these previously unknown features. Where necessary, and where possible, we have corrected our observations to take account of information given in the manual.

Sign-on Procedure To gain access to the system, the user first switches on the power for each of the terminal components, five switches in all. A keyboard command then activates software in the videotex decoder to produce a menu display on the monitor screen. On most users' terminals, this menu has a single item which consists of the literal command sequence (for example, ATDT5551212) that would be sent from a computer to a modem to cause the modem to dial a telephone number. Although it would not be self-evident to a first time user, typing the digit that corresponds to the displayed menu item causes the modem to dial the RWIS computer to give the user access to the RWIS system itself.

The sign-on procedure is simple to perform. A user who uses the system frequently would probably prefer to have one power switch instead of five switches to turn on. This would also reduce the chances of a user forgetting to turn off all of the components at the end of a terminal session.

RWIS Menu The main menu contains a text display consisting of 18 selections arranged in two columns. All RWIS text displays can display 40 characters per line, and about 20 usable lines per screen. Each menu item consists of a numbered label that describes an RWIS data base function. The menu selections are ordered to provide logical groupings of RWIS' functions. The groups are: current weather information, forecast weather information, and road conditions.

There is no prompt telling the user what to do to make a menu selection.

However, it is probably not difficult for the user to figure out that typing a menu selection number will cause the system to go to the function described by the menu item. The user can either type the selection number on the computer keyboard, or punch it on the hand-held commander. Once the selection number has been entered, it is displayed at the bottom of the screen. The user can then either press the RETURN key to have the system go to the selected function, or use the delete key to erase the selection number and enter another selection number. All of the menu selections worked, except the 'HELP' function, which apparently had not been installed.

Instead of using the menu, the user can type commands consisting of sequences of two or more letters and numbers to get access to different functions. We did not observe the use of these commands because we did not find out about them until we obtained a user manual where they are described. The manual gives a list of commands to use for access to different functions. The RWIS system developers evidently made some effort to define mnemonic command sequences. For example, typing GW would cause the system to go to the General Weather function. However, the mnemonics are not consistent. If the user typed SR expecting to get Station Reports, the user would be wrong. To get station reports, the user has to type SA.

The main menu is well designed on the whole. However, there should be prompts telling the user exactly what to do to make menu selections; and there should be an operational 'HELP' function.

In the following paragraphs, we will review each of the menu selections in turn.

1 General weather This displays a weather map covering central eastern North America. According to the user manual, the map is updated every three hours. The map shows enough geographical features to permit locating the weather systems that might appear on the map. The weather information shown on the map includes isobars, up to three intensities of cloud cover, areas of precipitation, and locations of weather fronts. There are also symbols available for showing such things as the centres of high and low pressure systems, types of precipitation, and thunderstorms. On the right of the screen there is a legend giving the meanings of the weather symbols. The top right corner of the screen shows a date and time.

The map display is a standard weather map; and to the extent that a user would be familiar with how to interpret a weather map, the display is well designed. For the most part, colour is properly used to enhance the ease of reading most of the important information on the map. In keeping with good practice, most of the weather information is redundantly coded with both a shape and a colour representation. The only weakness in the map display is the tendency for the cloud cover representation to obscure other information on the map.

The format of the date and time is not one that is easy to read. It is

not clear, for example, that APR 100700L means that the map was current on April 10th, at 7:00 AM, local time. The legend explaining the map symbols is rather cryptic. In fact, symbols are described by abreviations that may themselves require further explanations. Also, the whole legend cannot be seen all at once. When the display first comes on, the legend shows codes for half of the symbols. Pressing a command key causes the legend display to be replaced by codes for the other half of the symbols. Having the legend available for viewing beside the map is convenient, and better than having to put the legend on a completely separate screen. However, an arrow symbol pointing to a letter F is the only indication that there are two sections to the legend display. It would be better to use the message line at the bottom of the screen to give a natural language instruction on how to see the other half of the legend.

2 Ontario weather This produces a weather map display that is the same as the previous general weather display except that the map covers Ontario and south western Quebec, at about twice the scale of the central eastern North America map. Everything said in connection with the previous display applies to the Ontario display. The Ontario map appears to be only a literal magnification of the Ontario section of the North American map. That is, it does not contain any weather details that cannot be seen on the North American map. Since weather systems cover such large geographic areas, the North American map would likely be more useful to a sophisticated user, particularly since the Ontario map does not show any local weather information that cannot be seen on the larger map.

3 Radar - King City This contains the radar display from the King City weather radar. The display shows the location and intensity of precipitation for a radius of about 200 kilometers around King City. The centre of the display corresponds almost to the centre of District 6, and it covers southern Ontario from the shore of Lake Huron to the eastern end of Lake Ontario.

Precipitation is shown by overlayed areas which are colour coded to represent the intensity of the precipitation. A legend on the left side of the display shows what rain rate each colour represents. When we conducted our review, the display showed colour codes representing a logarithmic progression of rain rates from 0.25 to 32 millimeters per hour. However, the illustration of the King City radar given in the user manual shows a rain rate scale from 0.25 to 64. Also, according to the manual, the radar shows precipitation either as rain or snow. The manual does not say if the same colour codes and rate scales are used for both rain and snow. In addition to showing precipitation, the radar shows the numbers and bearings of lightning strikes.

The date and time of the display are shown in the bottom left corner of the display. The display is up-dated every 10 minutes. According to the manual, the user can type commands that will produce any of the six previous

displays. This permits the user to review the past hour's progress of whatever system is moving through the area.

The scale of the display, and its rate of up-dating, permit the user to keep close track of any system of precipitation moving through the area. The scale of the display, combined with the typical speeds of weather systems, gives the user anywhere from one to four hours advance notice of when precipitation will reach a particular location. This range of times is close to the time frames that operating maintenance personnel have for making decisions about current operations. This may account for some of the reason why most of the maintenance personnel thought that the radar display was one of the most useful features of the system.

Our only comments on the radar display concern the colour coding, and the rain rate scale. The colours representing the different precipitation intensities do not correspond to any natural colour progression that would permit the user to intuitively interpret precipitation intensities without referring to the legend. A colour coding that used light colours for light precipitation, and dark colours for heavy precipitation would be more natural. An alternative colour scale would be to use colour temperature to represent precipitation intensity, where blue represents the low end of the spectrum and red the high end of the spectrum.

We do not know if the snowfall precipitation scale is the same as the rainfall scale. If it is, a scale with fewer categories and a linear progression for coding the intensities would also be more relevant to operations personnel. The difference between 1 and 2 millimeters/hour is inconsequential for road clearing. The difference between 16 and 32 millimeters/hour is not at all inconsequential. For operations, just three or four leveis of precipitation intensity would likely be adequate. This would also make it easier to define intuitively interpretable precipitation intensity codes.

4 Radar - Exeter This is almost the same display as the King City radar display except that it is centered on Exeter. The Exeter display uses different colour codes for the precipitation intensities; and the scale of intensities on the Exeter display goes from 1 to 128 millimeters/hour instead of from 0.25 to 32 millimeters/hour as on the King City display. The legend on the Exeter display showed blank colour code boxes for rates from 32 to 128 millimeters/hour. There is no indication of how the user should treat these blank codes. Again, the Exeter colour codes do not yield a natural perceptual scale of intensities.

It would be more convenient for the user if both radar displays used the same colour coding system. If the user used the split screen facility to view both radar displays at the same time, the same actual rates of precipitation in the areas covered by the displays would appear to be different rates according to the colour codes in each display.

The Exeter screen also uses another unique time display format. The lower left corner of the screen shows, for example, 1540 Z. We interpret this to mean 15:40 Universal Coordinated Time, which used to be called Greenwich Mean Time. The time should be shown as local time, as on the King City display.

In connection with both radar displays, Radio Room personnel observed that although the displays were never supposed to be more than 10 minutes old, they were sometimes 20 to 40 minutes behind schedule.

5 District Weather This display shows a map of the highways in the District. Small clusters of weather information symbols are shown at points that appear to correspond to locations of airport weather stations. Each cluster shows the temperature, and small literal drawings of clouds and sun that are meant to convey cloud and precipitation conditions around the stations. Standard meteorological symbols are used to convey wind direction and speed.

The top right corner of the display shows a time in the format different from ones used on other pages. In this case, the format is, for example, 1000 EST. Presumably this would mean that the information in the display was current at 10:00 AM, Eastern Standard Time. According to the user manual, the District Weather is updated every hour. Since different RWIS functions are updated at different times, it might be helpful to always show both the time of the current display, and the time when the next update is to occur.

According to the user manual, there is a command that will cause the system to display a legend that gives the meanings of the weather symbols. The manual does not show what the legend looks like. There is no indication on the screen that there is a legend available. The page should be modified to indicate that a legend is available.

The cloud and sun symbols are designed and presented in a way that makes it difficult for the user to interpret them as weather facts and figures. In fact, the display can give a misleading visual impression of the District weather. On a cloudy day, for example, because the symbols are clustered around each reporting station, the visual impression could be that the District weather is clear except for five or so isolated cumulus clouds, each hovering over a local airport. To give the user an at-a-glance summary of the station reports, it would be better to consistently use standard meteorological symbols.

6 Station Reports When this function is selected, the system displays a menu of items corresponding to the five weather stations shown on the District Weather display, plus a menu item for "other stations". If the user selects a local station, the system produces a text display showing weather data for the selected station. The "other stations" selection produces another menu that lists all of the weather stations in Ontario.

When the user selects a particular weather station, the display shows three columns of weather data, with the data labels shown on the left side of the screen. Each column shows data for observations taken at a particular hour. Observations for the most recent hour are in the left data column; observations for the next most recent hour are in the centre column; and observations for two hours previous are shown in the right column. The data in each column include sky condition, visibility, weather conditions, obstruction to vision, atmospheric pressure, temperature, dewpoint, wind direction, and wind speed. At the bottom of each column there is a space for remarks. The user manual does not say what types of information the user might expect to see in the remarks space.

The display is generally easy to read. However, the user would have to have some degree of weather sophistication to interpret what the data mean. In addition, if the user is meant to be able to draw some inferences about the trend of the weather over the last few hours, the columns should be rearranged so that the most recent hour is the rightmost column instead of being the leftmost column. This would make the ordering of the columns correspond to the strongly conditioned response of reading spatial representations of time as if time flowed from left to right.

The heading of the display does not give the name of the station whose data are being viewed. Instead the station's three letter aviation identifier is shown. Thus the user either has to know these identifier codes, or remember the name of the station that was selected from the menu. The time of the dispiay is shown in the upper right corner as, for example, 1100-0900. We assume 1100-0900 would mean that the display showed data for the period 9:00 AM to 11:00 AM, local time. The data in the display represent a mixture of current and obsolete measurement units. For example, atmospheric pressure is given in miilibars instead of kilopascals. Visibility is given in miles (according to the display) while wind speed is given in kilometers per hour. Actualiy, the user cannot be sure what unit is used for visibility. According to the text of the user manual, visibility is in kilometers; yet the illustration in the manual shows visibility in miles.

7 36 hr. forecast This display is the same as the weather map display for the General Weather (menu item 1) except that the map covers almost all of Canada and the United States instead of just the eastern half of central North America. The display shows what the weather map is predicted to look like at the date and time shown in the upper right corner of the display. The forecast, as the menu label implies, is for about 36 hours from the time that the display is being viewed. According to the user manual, the display is updated every 12 hours. Since the 36 hour display and the general weather display have the same designs, our earlier observations about the general weather display also apply to this display.

8 24 hr. forecast This is the same as the 36 hour display except

that it covers a smaller area, which is the same area as the general weather display covers. Again, our observations about the general weather display also apply to this display. In addition, we note that it would be useful to have the 36 and 24 hour displays cover the same geographic area. This would make it easier for the user to compare the two forecasts, particularly on the split screen facility.

9 Winter precip. This selection produces a menu listing selected airport weather stations. When a station is selected, a display appears showing two columns of data, with the data labels on the left. The left data column is labelled '1st PERIOD FORECAST', and the right hand column is labelled 'NEXT 12 HR PERIOD'. We interpret these headings to mean that the left hand column is for the next 12 hours, and the right hand column is for the succeeding 12 hours. According to the user manual, the forecasts are issued four times a day. It would be easier for the user to interpret the data if the column heading showed the actual time period for which the forecast data are valid; for example, "FORECAST FOR 04:45 AM TO 04:45 PM".

The data given in each column include the amount of precipitation; type of precipitation; snow amount; start, change, and end of precipitation; and wind and temperature information. The data fields in this display all contained the message 'NO DATA' on the three occasions when we had access to the system. Because it was late in the season, it may have been that data were not being supplied for this function.

The winter precipitation data would obviously be useful to maintenance operations personnel. The display design makes it easy to read the information from the display. The columns in the winter precipitation display are arranged so that time progresses from left to right instead of from right to left as in the station reports display. Also, the winter precipitation display gives the actual name of the reporting station instead of the three letter identifier shown in the station reports display.

10 Significant weather warnings This selection produces a menu in the form of a map showing three regions: one region includes northwestern Ontario and Manitoba; the next region includes the rest of Ontario; and the third region includes almost all of Quebec. Selecting one of the regions produces a text screen which would describe the nature and location of any severe weather in the region. There were no warnings in effect on any of the occasions when we observed the system.

The design of the weather warnings function is quite adequate. However, since it is a warning function, it would be better to have an indicator on the main menu that would show whether or not any warnings are in effect. Users who use a system routinely soon start ignoring functions that only occasionally contain information of any interest to them. Without an indicator on the menu, chances are that users will miss warnings when they actually occur.

11 Public forecast This selection produces a menu consisting of a list of AES's Ontario forecast regions, and a map showing the location of each region. When a region is selected, a text screen appears showing the public forecast for the region. The forecast reads essentially the same way as one hears a forecast read on a public radio broadcast. The public forecast function is easy to use; and anyone who can understand a broadcast weather report can understand the information conveyed by this function.

12 Road conditions This selection produces a map of the District. The map shows the highways in the District, and the locations of patrol yards. The highways can be shown in different colours to indicate the road conditions. A flashing dot can also be displayed on the map to indicate that a road is closed.

A legend at the top left of the display shows what road condition each colour represents. The labels used in the legend are rather cryptic. We found that users had to take some time to figure out what some of the labels meant. It is not difficult to interpret 'RB/Dry' as road bare and dry, but labels like 'RH', or 'RSL' may be less obvious. The codes would not likely be a problem for practiced users, but they would be for occasional users.

There are 10 colour codes used for the road conditions, plus one more colour to indicate missing information. This means that the user has to be able to look at a section of road on the map and discriminate the colour that the road is shown in from among the 10 possible colour codes. Under good conditions, people with normal colour vision can discriminate about 15 colours. People with colour vision anomalies can seldom discriminate more than about 8 colours. The nature of a map display makes it less than ideal for making fine colour discriminations. In our opinion, the colour coding requires making finer colour discriminations than one should expect average users to be able to make; certainly finer discriminations than any colour anomalous user can make. It might be worth asking a panel of users to help define a smaller number of meaningful road conditions categories.

Except for the colour coding problem, the road conditions display provides a quick way of seeing what the District's road conditions are. If the display were to be improved it would be to reduce the colour discrimination load by reducing the number of conditions coded, or by adding another type of redundant coding so that the user does not have to depend entirely on colour.

13 Road maintenance This selection produces the same map display as the road conditions display, except that the colours of the roads represent the type of maintenance operation currently underway. The legend shows 8 colours representing operations such as sanding, plowing, and so on. There is also a colour code for missing data. The display also shows road

closures. In the legend for this display, the labels are in plain English so that the user has no difficulty interpreting what operations the different colours represent. The smaller number of colour codes also means that there is less chance of error in discriminating the colours.

In both the road conditions and maintenance operations displays, there are no conditioned associations between the colour codes and their meanings. Thus the user either has to remember what each colour means, or constantly refer to the legend for the meanings of the codes. This is more reason for seeing if the number of codes could be reduced. For example, it may not be necessary, for most purposes, to discriminate among sanding, salting, and sanding/salting.

14 Road report program This is a data entry function. When it is selected, a menu appears offering the user choices of adding a new report, modifying a report, and viewing a report. Only specific authorized users can gain access to the data entry functions. If the user chooses to add a report, the system displays a blank form for the user to fill. The information to be filled in is the information that patrols report in their regular reports; local weather conditions, road conditions, and current operations. At the bottom of the screen there are instructions on how to move the cursor from field to field, and on how to send the report, or exit from the program.

The input form has 12 fields to be filled in. There are no default entries to save the operator from having to type frequently occurring entries. The form would be simple to fill in for a single user doing a single form. However, during the trial, the Radio Room was entering data for all of the patrols, so the data entry task was not inconsequential. On a conventional computer system the data entry could be considerably speeded up by using defaults and menus for entering the information. This may not be practical on RWIS however.

According to the user manual, typing a question mark in a field causes the system to display a help message for that field at the bottom of the screen. Since we did not have an opportunity to experiment with doing any data entry, we were unable to assess the system's procedures for validating entries, or its ability to deal with input errors.

The displays for modifying reports and viewing reports are essentially the same as the data entry display except that an already filled in form appears on the screen. The user can then view or modify the contents of the form depending on what menu selection was made when the display was requested.

15 X-sections When this selection is chosen, the system displays a menu offering choices from Toronto - Montreal, Highway 400, and Highway 417-17. Choosing one of these options produces a display representing a

longitudinal cross-section of the chosen highway. The Highway 417-17 section covers the highway from Pembroke to the Quebec border. On each display, the highway is represented by a horizontal bar across the screen about one third of the way down the screen. A scale below the bar shows distance graduations, and the locations of major cities along the route. Colour coding of the bar indicates the condition of the road at different point along the route. Above the bar representing the road, there is an area symbolizing the sky. This area can display clouds, rain, snow, and so on to represent the weather conditions at different points along the way. The bottom part of the screen shows a legend describing the meanings of the colour codes and weather symbols.

The cross-section display provides a quick and easy way of seeing the conditions along a major route. The design of the display has limited the codes and symbols to information that would be relevant to drivers using the route. The codes and symbols are also easy to discriminate from one another. On the whole, the cross-section display is the best designed of all of the system displays.

16 Ontario Districts This selection produces a map of southern Ontario showing MTC District boundaries. The Districts are numbered so that typing a District's number would give the user access to the data base for the selected District. Because RWIS is only a test system at this time, there are no data stored for most of the Districts.

17 HELP If the user selects this page the system produces a message saying that there is no such system page. This seems guaranteed to frustrate the user. The system should either give a name and telephone number to call for assistance or the selection should be left off of the menu altogether.

18 EXIT This selection disconnects the user, and displays a thank-you message with a telephone number to call for more information. It would be useful to include in this message a reminder to turn off all of the terminal components.

General Observations From the perspective of the user interface, the system is generally well designed. As described in connection with our review of individual RWIS functions, there are a number of detailed improvements that could be made in individual functions.

Like all Telidon-based systems, RWIS is slow compared with conventional computer systems. Screens take from 5 to 10 seconds to display. Heavy system users generally find display production times of more than one or two seconds to be a significant annoyance. However, the high data volumes associated with graphics displays would make it impossible to produce fast response times on RWIS using conventional telephone line computer

communications.

As mentioned earlier, there should be a standard format for presenting date and time information. Since different functions are updated at different times, it would be helpful if the valid period of each display was also given. The date and time information should also be displayed in a standard location on the screen.

The system could be made easier to use by providing more user prompts and reminders. At least one of the displays gives no indication that a legend is available. On other displays an arrow and either the letter F or letter B is the only indication that there is more legend information available. In fact, most of the displays have one or two lines at the bottom of the screen that could be used to provide the user with more detailed reminders and instructions.

The system automatically disconnects if the user does not enter a command within a time span of three minutes. This is a rather short time for users who are likely to be interrupted while using the system. Ten to 15 minutes is a more typical time to allow before automatically disconnecting a user. If there is substantial system overhead associated with having inactive users connected to the system, it would be proper to have the system generate a flashing warning on the screen to let the user know that the system is about to be disconnected. The user could then retain the connection by entering a keystroke command to cancel the warning, instead of having to initiate a new connection all over again.

The monochrome printer used with the terminal provides a convenient way of recording screen images. However, some colours in the graphics do not show up clearly on the printout, so the printed copies serve primarily as reminders of how the original screens appeared. All text information prints out clearly. Some users thought the printouts could be used for legal purposes in the event of a lawsuit connected with maintenance operations. Other than this possibility, they did not suggest any general applications for the printouts. However, it is likely that users will only find uses for the printouts after they have had lengthier experience with the system.

Finally, except for the public forecast, RWIS weather information is presented in a level of detail, and in formats that usually require some training in meteorology before the user can interpret the information. Only one of the users that we interviewed had any training in meteorology. This exception was someone who happened to have had meteorology training as part of taking flying training. Most of the intended users do not know how to interpret weather maps. Nor do they have the knowledge necessary to combine items of weather data to make inferences related to operational decisions. Thus, although the RWIS user interface is generally adequate for conveying the information that it is intended to convey, the users did not have the training that would be needed for applying the information to operating needs.

User Manual We received a draft user manual after the first draft of this report was produced. Since we did not conduct the interface review with the user manual at hand, we will only review the main features of the manual. Also, since the manual was obviously a draft version, we ignored faults such as typographical errors.

The manual contains four main sections: an introduction; a section describing how to set up the terminal; a section on how to get access to the RWIS computer and the various RWIS information functions; and a section containing descriptions of the individual functions. There are two appendices. Appendix A lists the typed command sequences that can be used instead of menu selections to get access to the different RWIS functions. Appendix B gives legends that explain the various meteorological symbols used on RWIS displays.

The manual contains, in our opinion, only the minimum amount of information that would be needed to operate RWIS. The version we reviewed is obviously in an unfinished state. The pages were not numbered; the table of contents lists only section headings; and there is no index. To find out about a particular operation or feature, the user would have to search the manual page by page to find the needed information.

The section on setting up the terminal is quite terse. It does not give instructions in a step-by-step fashion. It is difficult to judge the adequacy of the instructions without trying to use them to set up a terminal. However, the instructions are written using computer communications technical language that might not be familiar to many users. There is only a rough hand lettered diagram showing the wiring interconnections among the terminal components. The reproductions of the photographs of the terminal are of the quality that one gets when a photograph is copied on an office duplicator. We assume that the final version of the manual will provide more legible photographs.

The subsections that describe the individual RWIS functions are written in a more or less standard format which consists of an illustration of the RWIS screen; information about when and how often the function is updated; and a listing of the types of information and data that can be read from the screen. The illustrations of the screens are copies of the black and white printouts produced by RWIS terminal printer. The subsections do not give any instructions about how to interpret or use the data that are presented in different information functions.

Taken as a whole, the user manual provides two main types of information that would not be evident from just operating the terminal. The manual gives the typed command sequences that can be used instead of the menu selections; and it gives the times at which different data base functions are updated. Except for providing these two types of information, the manual does not seem to us to do much to augment what the user could learn just from operating the system.

If the manual is reprinted in the future, the illustrations should be reproduced at print quality standards. An index, or more detailed list of contents should be added. And an effort should be made to convey information in a written style suitable for non-technical readers.

5.3.2 RWIS Indirect User Interface

We found that there were no specific procedures for communicating RWIS information to maintenance personnel at the patrols. To do this, someone in the Radio Room, or in the District Office, would have to view the RWIS displays and radio the information to patrol personnel. This could be done on the initiative of Radio Room or District Office personnel; or it could be done in response to patrol personnel calling in and asking for information. Although RWIS information was passed to the patrols during the evaluation period, it seemed to be done only occasionally. There was certainly no standard procedure for communicating this information.

In the case of public information services, the RWIS road information reports could replace the existing radio based road reports. Since the information in RWIS road reports is the same as that in the existing road reports, it did not appear that the RIO would be able to offer the public any substantially new information services as a result of installing RWIS. Since the RIO is structured primarily for mass distribution of information, the main application of RWIS would be to incorporate RWIS information into information now supplied in current services. As described earlier, the RIO is not set up to provide members of the public with individual information responses.

RWIS information is, in fact, not the type of information that an operator could pass on in sufficient detail to an end user, whether the end user be a member of the public, or a patrol supervisor. It is not, for example, an enquiry system where the end user wants to get a specific item of information such as the status of an airline reservation. Instead, RWIS provides a wide range of complex detailed information that has to be integrated and interpreted by the user before the user can make appropriate responses to road or weather conditions.

In theory it might be possible for a person in the District Radio Room, or in the District Office, to monitor RWIS, interpret the information, and then call patrol personnel to tell them about significant weather trends. We do not think this would be a good idea. First, while it might be possible to do this in theory, achieving it in practice would be difficult. The District person would have to monitor RWIS and interpret RWIS data in terms of each patrol's local conditions. This would be contrary to the present, and we think well founded, belief that patrol personnel are in the best position to formulate operating decisions from weather information. In fact, patrol personnel now have a good deal of autonomy in their day-to-day decision making. Having District level personnel continually calling with weather

information would only interfere with this autonomy and create resentment.

In our opinion, the end user has to have direct access to the the system to be able to meaningfully use the system. This implies that for maintenance patrols to benefit from RWIS, RWIS would have to be installed at the patrols. In the next section, we will describe findings from the critical incident analysis that indicate the nature of the benefits that the patrols could derive from having direct access to RWIS.

5.4 Critical Incident Analysis

In winter operations, the response to a storm constitutes the critical incident that best describes the major function of a patrol. For the purposes of this discussion, a storm means any weather disturbance that requires maintenance actions. In describing the operations response we will concentrate on aspects that are influenced by having information about the weather. As a preface to describing the response to a storm, we note that no two storms are the same, so we have not attempted to describe all of the response variations that could be made to all the possible variations in weather behaviour.

The response to a storm has several phases. We will describe each phase in turn, and for each describe the impacts that knowledge of the weather can have on how operations during a phase are managed. After we have described the weather impacts on managing operations during a storm, we will briefly deal with weather impacts on routine maintenance operations. At the end of the section, we will summarize by describing the types of weather information that can be used by patrols in managing operations.

5.4.1 Storm Alert

When there are no salting or plowing operations required, MTC maintenance crews carry on with various routine maintenance tasks such as repairing signs, road patching, and so on. The trucks used by the maintenance crews for routine maintenance are also used for snow plowing operations. The plows are removed from the trucks when the trucks are used for routine maintenance, so the plows have to be put back on when plowing starts. It takes up to an hour to mount a plow, and it may take up to two hours to prepare all of a patrol's equipment.

When the patrol is alerted to a storm on the way, the first decision that has to be made is when to call in trucks to have the plows mounted. Salting units are normally ready to operate with little or no advance notice. The patrol supervisor, or the patrolman, also has to decide if and when to call out the patrol's cont acted services. Contracts specify the amount of time that is allowed for a contractor to respond, typically 30 to 45 minutes. When called out, the contracted personnel and equipment can either be put on standby, or be put immediately into operations. Being on standby means

having the equipment at the patrol's yard ready to start operations as soon as the order is given.

A number of the patrol supervisor's decisions depend on the timing and intensity of the storm. First, the patrol supervisor does not want to take crews off current maintenance duties any sooner than necessary because any time spent after equipment preparation and before operations start is essentially non-productive time. Also, the supervisor does not want to call out contracted services until anticipated clearing operations exceed what the patrol's permanent resources can handle. Nor does the supervisor want to have to be unnecessarily paying for contracted services to be on standby.

The timing of the response to the actual commencement of the storm is critical. Ideally, salting should start at the same time as precipitation starts. Traffic will blow salt off the pavement if salting is done on dry pavement. There are also likely to be complaints from the public if salt is seen on dry pavement. On the other hand, if salting does not start until some time after snow has started to fall, traffic will pack down a solid layer of snow that will be difficult to melt or plow off. Plowing can start as soon as there is enough snow to require plowing. Generally the requirement to start plowing is self-evident. However, until plowing is required, the plowing services may be on non-productive standby time.

The timing of the arrival of a storm also interacts with shift schedules. Probably the best time for a storm to arrive is about two hours after a shift changes. Then the shift coming on duty can prepare the equipment, and have the rest of the shift to get operations underway. For other arrival times, the supervisor has to make decisions about whether or not to keep a shift on at overtime rates, or whether or not to let the shift go in hopes that the incoming shift will have time to prepare for the start of the storm.

5.4.2 Operations During a Storm

During a storm, operations management is fairly straightforward. The patrolman on the road can generally keep track of whether or not salting and plowing is being done adequately, and if necessary, can redirect crews to deal with trouble spots. If the storm is running a predictable course, the main concern is to keep salting to the minimum required to maintain melting, and to keep plowing to the minimum required to maintain bare pavement. Keeping the roads up to the Ministry's bare pavement standard while minimizing the expenditure of time and materials depends on responding correctly to temperature and precipitation fluctuations as the storm progresses.

The supervisor also has to be concerned about a large sudden increase in the intensity of the storm. If this occurs, the patrol will be dealing with what amounts to a storm within a storm. This possibility is most worrying at night because the patrolman cannot see the sky conditions.

5.4.3 The End of a Storm

Just as it is of value to anticipate the beginning of a storm, it is of value to be able to anticipate the end of a storm. If the end of the storm can be closely predicted, the supervisor can start winding down operations to minimize unnecessary time and materials expenditures. For example, each salt application will melt a certain amount of snow or freezing precipitation. If one can predict the end of precipitation, then the last salt application can be timed so that it will correspond to the amount of precipitation left to fall before the end of the storm. The supervisor can also save on contractor time, as well as on the patrol's own overtime expense by starting to let crews go shortly before the storm ends.

At the end of a storm, the patrol supervisor also has to make decisions about post-storm cleanup operations. During a storm, operations are concentrated on roadways, with clearing of freeway ramps and intersections being given a lower priority. When the storm ends, the patrol must clear intersections and ramps as soon as possible. The patrol supervisor also has to decide on post-storm preventive operations such as clearing back snowbanks. If high winds, or another storm, are on the way, banks should be cleared. If the weather is going to be calm and warm, nature can be left to clear away the leftover snowbanks.

5.4.4 Effects of Weather on Other Operations

Almost all road maintenance operations, including operations during the summer season, depend to some degree on weather conditions. Certain operations can only be done when the temperature is above a certain minimum. Other operations require dry conditions. Even if an operation can be performed in almost any type of weather, personnel productivity will be higher if outdoor work can be done in good weather. If the patrol supervisor can accurately predict weather conditions, crews can be assigned to tasks that are appropriate for the weather. If the supervisor has no weather information, time will be wasted on sending crews out to perform tasks that turn out to be impossible to do because of an unanticipated change in the weather.

5.4.5 Sources of Weather Information

The analysis of the maintenance operations shows that a substantial proportion of the outcomes of the patrol supervisor's decision making depends on the weather. For this reason, patrol supervisors use whatever weather information they can acquire to try to maximize the performance of their patrols. At present, the patrol personnel depend on three main sources for weather information: broadcast media, internal weather reports distributed from the RIO, and information from nearby patrols. Information from nearby

patrols is used during storms to keep hour-by-hour track of the progress of the weather.

The findings from the critical incident analysis, as well as from the user task analysis, show that the weather information needs of the patrols include needs for both long range and short range forecasts. Long range information can be used to plan operations going on between storms. Short range forecasts, spanning from a few minutes to a few hours, are important for managing operations during a storm. The range of RWIS weather information functions corresponds well with the range of weather information needs of patrol personnel. But to exploit RWIS information, patrol personnel must have better access to it. In the Discussion section of the report we will address the question of whether or not RWIS should be installed in patrols.

5.5 Summary of Results

The user task analysis and the critical incident analysis suggests that the information supplied by RWIS has primary applications in operational decision making at the level of the maintenance patrols. RWIS also has public information applications, but it does not supply much information that is not already available to public information personnel, nor does it supply information in a form that is suited for redistribution through the channels that the public information services now use. For the public information services, RWIS is a convenient way of checking certain types of information, but it does not substantially change or improve the nature of the the public information function.

Although a number of detailed improvements could be made in the RWIS direct user interface, it is generally adequate for mediating the information that the system was designed to convey. However, the indirect RWIS user interface is not adequate. There are no procedures for getting information from the existing terminals to users at the patrol level. The District Radio Room is not set up to act as the interface between RWIS and the patrols; nor is it practical for a terminal operator to pass on a detailed understanding of road and weather information to an end user by some other medium.

RWIS provides information that is relevant to maintenance operations decision making. The long term forecasts can be used in planning day-to-day operations. The short term forecasts can be used to prepare for responding to bad weather. And the very short term forecasts implicit in the radar displays can be used to optimize operations during a storm. However, few users have the training that would permit them to effectively interpret and exploit RWIS information.

Although the results suggest that RWIS has applications at the patrol level, the design of the present trial does not permit assessing the degree to which patrols could exploit RWIS in practice. The most obvious way to assess patrol applications of RWIS would be to test the effects of installing

RWIS in patrols. We will consider this possibility in the Discussion section that follows.

6.0 DISCUSSION

From the information gathered to this point in the evaluation, the primary application of RWIS appears to be in the form of weather information supplied to the patrols. However, we can only speculate on the benefits that could be realized by providing the patrols with access to RWIS information. During the evaluation trial, there was no system for getting RWIS information to the patrols; and there were no RWIS terminals installed at any patrols. The critical incident analysis suggests ways in which the patrols' operating efficiencies are influenced by the degree to which patrol supervisors wisely use weather information, but there is no evidence about what would happen if patrols actually had direct access to RWIS.

An obvious way to assess whether or not RWIS would be useful to the patrols would be to install terminals in a sample of patrols, and see whether or not their efficiencies improved as a result. Detailed records are kept on each patrol's expenditures of time and materials, so it would be possible, in principle, to assess the efficiency of RWIS equipped patrols compared with patrols that did not have RWIS installed. While such a test would be feasible, there remains a question of whether or not such a test would be worth conducting. In particular, would the potential operational benefits come close to the estimated cost of operating RWIS in patrols?

We have no way to directly assess the benefits of installing RWIS in patrols, but we can use RWIS operating costs to estimate the benefits that patrols would have to realize to be able to justify the installation of RWIS terminals. Appendix A contains the details of a cost-benefit analysis in which the costs of installing RWIS at all of MTC's 252 patrols were used to estimate how much the patrols would have to save on operating costs to justify the RWIS investment. The analysis was done as an ordinary capital investment calculation.

The analysis in Appendix A shows that a relatively modest benefit would be required to justify installing RWIS terminals in patrols. The amount of the total required benefits would represent in the order of two percent of MTC's total winter maintenance costs. This would be equivalent to each patrol saving from 1,000 to 2,000 dollars per month on operating costs during winter operations. We emphasize however that we have no way of determining from the present evaluation if the required benefit could be realized. It is clear that RWIS provides information that is relevant to patrol operations management, but it remains to be seen if patrol personnel could actually exploit RWIS to achieve the required benefits in practice. The figures in Appendix A merely show that the cost of operating RWIS is not inordinately

high relative to the benefits required to justify the system.

An informal sensitivity analysis of the investment model in Appendix A shows that the net present value outcome is mainly sensitive to the number of terminals that are installed. In doing this sensitivity analysis, we took account of the discounts that would be obtained for volume purchases of the terminals. With 100 terminals installed, each patrol would have to obtain a monthly benefit of about 1200 dollars to realize the same investment gain as is shown in Appendix A for all 252 patrols. In the case of 50 patrols, each patrol would have to achieve a benefit of 1400 dollars. If the system were installed only in District 6, each of its 14 patrols would have to obtain a monthly benefit of 2800 dollars.

We emphasize again that the cost-benefit analysis shows only the amounts of the benefits that would have to be realized to justify the cost of installing RWIS. While the analysis is based on reasonably accurate cost estimates, we have not attempted to specify how the benefits could be achieved. From the findings about patrol activities, and from knowledge of the winter maintenance budgets, the analysis shows that the required benefits are small relative to patrol operating budgets, but it remains to be seen if they could be achieved in practice. Similarly, we have taken no account of possible benefits related to the public information aspects of RWIS, or possible savings associated with litigation. Nor have we considered any intangible benefits such as convenience, and generally more systematic distribution of road and weather information within MTC. Finally, we have not considered any other applications for the terminal hardware; such as using them for management information applications, messages, and related applications.

At this stage of the evaluation, it appears that installing RWIS at the District Office level has a limited effect on patrol personnel because of the difficulty of getting RWIS information from the District level to the patrol level. In our opinion, if patrols are to exploit RWIS, RWIS has to be installed in the patrols. This would still leave the question of whether or not the patrol personnel could use RWIS to improve operations efficiency to the degree that would be required to justify the investment in RWIS. Although the estimated unit cost of using RWIS is modest relative to the size of a typical patrol's operating budget, it would be wise to test whether or not patrols find that RWIS can be used to gain the expected benefits.

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Appendix A

Cost-Benefit Analysis of Installing RWIS in Patrols

Table A1 shows a set of costs, an assumed dollar benefit, five years of cash flows, and a resulting net present value. The table is a cost-benefit model for describing the outcomes of investing in installing RWIS terminals at patrols. In the next paragraphs, we will describe each of the cost and benefit components that make up the model.

Starting at the top of the table: we have assumed an annual interest rate of 10 percent for the net present value calculation. Ten percent was chosen as a convenient round figure close to the current interest rate. For the situation at hand, the model is relatively insensitive to interest rate, so it does not matter if the chosen rate is a few percent different from Ontario's actual borrowing rate. The number of months of operation is the number of winter season months that RWIS would be expected to operate. The annual costs given lower down in the table are based on this number of months of operation. The inflation rate is a figure applied to the annual cash flows to take into account anticipated cost increases.

The number of operational terminals corresponds to the present number of maintenance patrols operating in Ontario. In addition, we have added a set of overhead terminals. These would be terminals located in District Offices, Radio Rooms, and the like. We assume that the overhead terminals would not directly contribute to operational benefits.

The capital cost shown for a terminal is the purchase price for a single terminal. We have not included in the table any provision for discounts that would be obtained for volume purchases of terminals. For example, if 288 terminals were purchased, there would be about a 30 percent volume discount.

The operating costs are shown in two columns; one representing monthly costs, and one representing annual costs based on seven months of operation per year. The maintenance cost is the cost of keeping terminals in operating condition. We were given an estimate of 40 dollars, plus or minus 20 percent, as the estimated monthly maintenance cost. Thus the figure used in the table is the upper limit of the plus or minus 20 percent range.

The cost of RWIS information is the cost of getting RWIS information into the central computer. This cost is the same no matter how many terminals are on the system. Next, the access port cost is the cost of providing communications access for each terminal to the central computer. The figure in the table is based on having one port for every four terminals.

The communications cost in the table is the estimated cost of telephone communications between the computer and each terminal. This figure would depend on the amount of RWIS usage, so it is difficult to estimate

accurately. We have chosen a figure for the table that should be high relative to the various figures that we were given for producing an estimate. In practice different patrols would have different communications costs depending on their locations. Some patrols could access the RWIS computer by local phone calls; other patrols could use common carrier data lines; and still other patrols would have to use conventional long distance lines.

In addition to cost data supplied to us by MTC, we have added an administration cost to cover internal administration connected with maintaining the terminals. We have not included any costs associated with MTC personnel supplying information for the system. If RWIS were installed in all patrols, the system could be used collect road report information that is now radioed in from the patrols. If this were done there would be no new costs; and if anything, some savings. We have also not included any costs for training users on how to interpret or use RWIS information. Patrol personnel do not now receive any formal training in using weather information. Since patrol personnel are so dependent on using weather information, such training could produce a benefit indpendent of whether or not RWIS was installed.

Under the heading of assumed benefit, we have entered the dollar benefit that an average patrol would have to realize each month to generate the net present value shown at the bottom of the table. The benefit figure was arrived at iteratively by entering different values until one was found that produced a respectable net present value relative to the total investment.

The cash flows for benefits, costs, and net benefits are derived from the sums of the individual cost and benefit figures given earlier in the table. The benefit cash flows are based on the number of terminals installed at patrols, not the total number of terminals. The net present value at the bottom of the table is from a standard calculation using the interest rate, the total capital investment, and the net benefit cash flows. We have chosen five years of cash flows because five years represents a common computer system life cycle.

The last figure in the table is the present value index. This is the ratio of the present value of the benefit cash flows over the present value of the cash flows plus the capital investment. The present value index gives an indication of the amount of the benefits relative to the size of the investment that has to be made to achieve the benefits. The value of the index would be close to 1.00 if the net present value was small relative to the size of the initial capital investment. There is no standard minimum for the present value index, but an index of 1.35 would likely be considered respectable. Although it is not appropriate to use internal rate of return for assessing public sector investments, we will mention that the rate for the case shown in Table A1 is well above what most private sector firms would set as a minimum for implementing capital investment projects.

Figure 1: Organizational structure and functions of the user group.

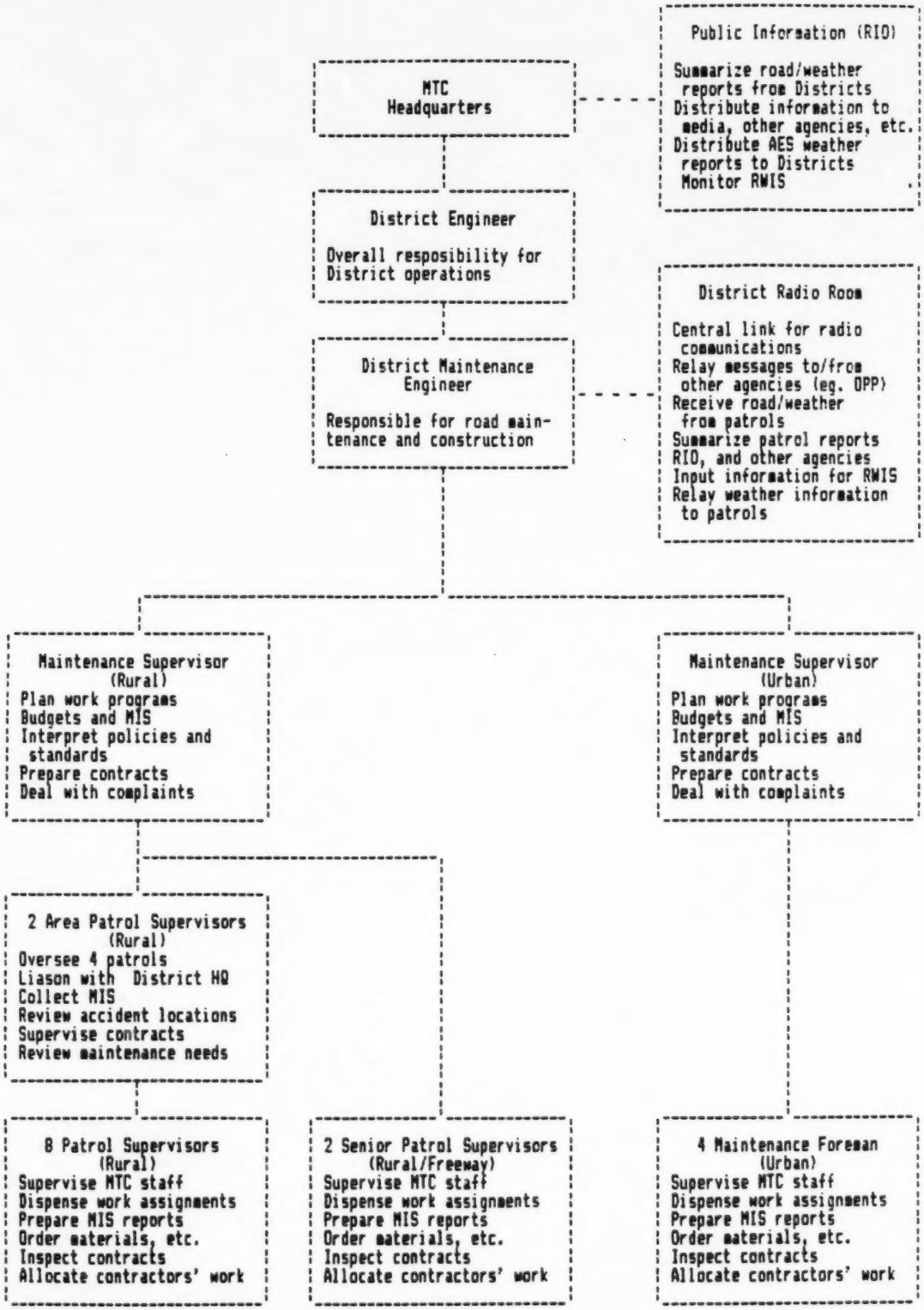

Table 1: User task analysis sample.

Position of Person Interviewed	Number Interviewed
District 6	
Headquarters Managers and Supervisors	4
Area Supervisors	2
Patrol Supervisors and Foremen	5
Radio Room	1
MTC Public Information Services	2
Total	14

Table A1: Cost-benefit analsis of installing RWIS terminals in patrols.

Parameters

Annual interest rate	10.0%
# of months operation/year	7
Inflation	4%
# of operational terminals	252
# of overhead terminals	36

Capitol Costs

Cost of terminal	$5,000
Capital	$1,440,000

Operating costs	Monthly Cost	Total Annual Cost
Maintenance per terminal	$48	$96,768
Total RWIS information cost	$20,000	$140,000
Access port per terminal	$125	$252,000
Communications per terminal	$200	$403,200
MTC admin. per terminal	$30	$60,480

Assumed Benefit

Year 1 benefit/month/patrol	$1,000

Cash Flows

Year	1	2	3	4	5
Benefit	1,764,000	1,834,560	1,907,942	1,984,260	2,063,630
Operating cost	952,448	990,546	1,030,168	1,071,374	1,114,229
Net Benefit	811,552	844,014	877,775	912,886	949,401

Net Present Value	$1,867,808
Present Value Index	1.35